



**Shell Global Solutions**

# **An Evaluation of Shell GTL Diesel**

## **–The Environmental Benefits**

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# Talk Synopsis

- OVERVIEW OF SHELL GTL STRATEGY
  - Incentives for GTL
  - Production Plans of Shell GTL (SMDS – Shell Middle Distillate Synthesis)
- ENVIRONMENTAL BENEFITS
  - Vehicle emissions
  - Biodegradability
  - Ecotoxicity
  - Sustainability
- CONCLUSIONS & RECENT ACTIVITIES

# Gas-to-Liquids

## -Incentives

- Large volumes of natural gas (NG) world-wide
  - 140 000 billion cubic metres (bcm) reserves
- However, annual global consumption is only 2 100 bcm
- Conversion of NG to liquid fuels an attractive option to take advantage of abundant gas reserves
  - Large and accessible global market for liquid fuels
  - Complementary to LNG and long distance pipelines

# Incentives

## -LNG & GTL in comparison

### Targeting different markets

LNG: Dedicated shipping and receiving terminals

Long term contracts

Power generation and gas markets

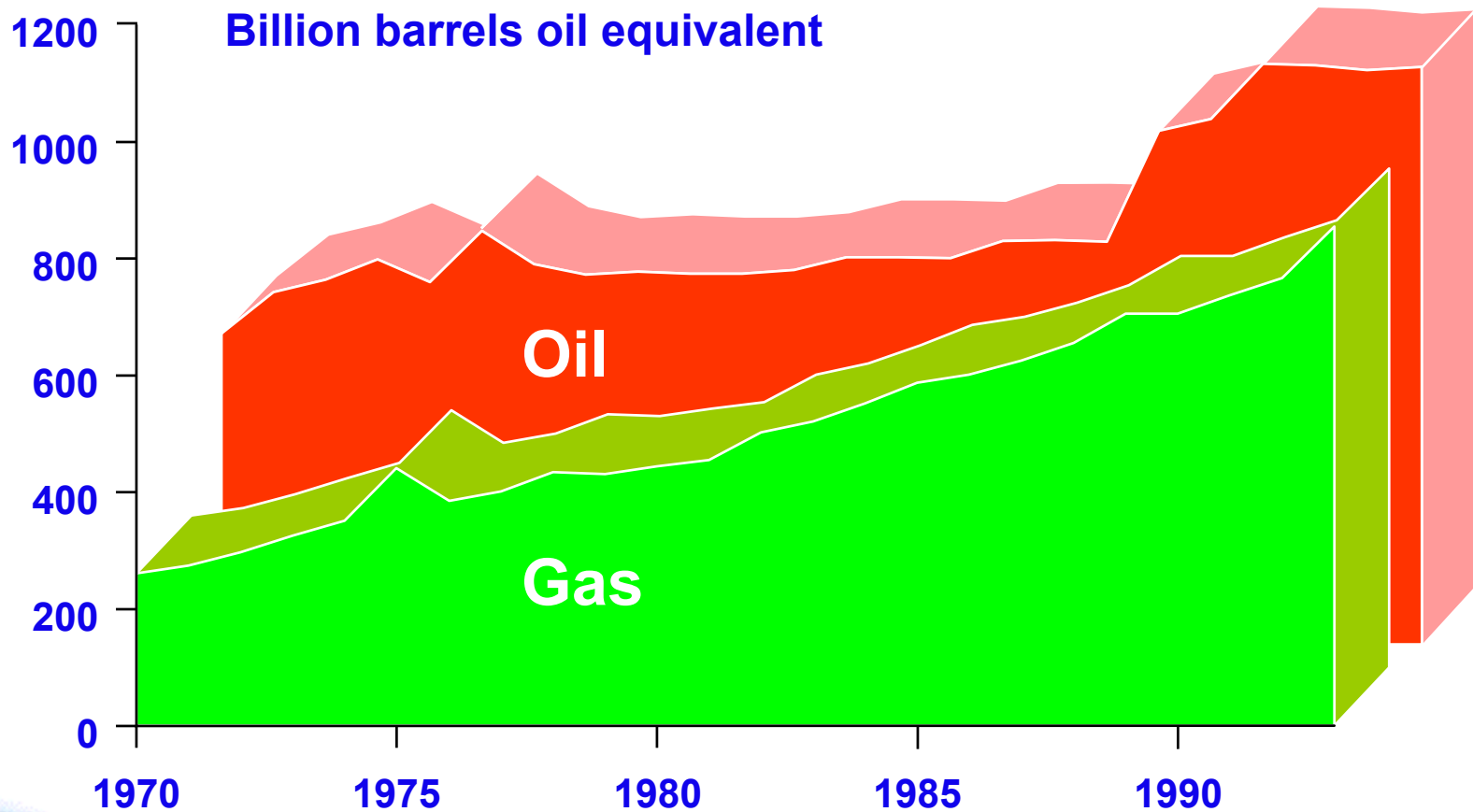
GTL: Unconstrained market with many opportunities

Potential to substitute for oil imports

High quality, ultra clean fuel applications

# Incentives

## -Proven World Oil And Gas Reserves



# Shell GTL (SMDS) Projects under Development

Strategy to commit several projects within this decade.....



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# Production Plans

- Shell is the leader in GTL technology with over seven years experience operating the only commercial GTL plant of its type in Bintulu, Malaysia
- Aspiration to commit to a number of GTL (SMDS) projects by 2010.
  - Developed a portfolio of SMDS prospects, progress for each is dependent on a variety of stakeholders (not under Shell's control).
  - E.g. economic and political conditions can change over time (Argentina is a case in point).
- Since we started the first study in mid 2000 many activities have progressed in parallel - technical as well as commercial.
  - Scouting studies have been completed for a number of locations
  - More detailed technical studies and basis of design engineering has progressed for the front-running prospects.



# Environmental Benefits

Investigation of potential advantages of Shell GTL diesel over normal diesel, including fate in the environment (biodegradability) and toxicity to aquatic organisms (ecotoxicity)

- Vehicle emissions
- Biodegradability
- Ecotoxicity
- Sustainability



# Emissions Performance

## Background

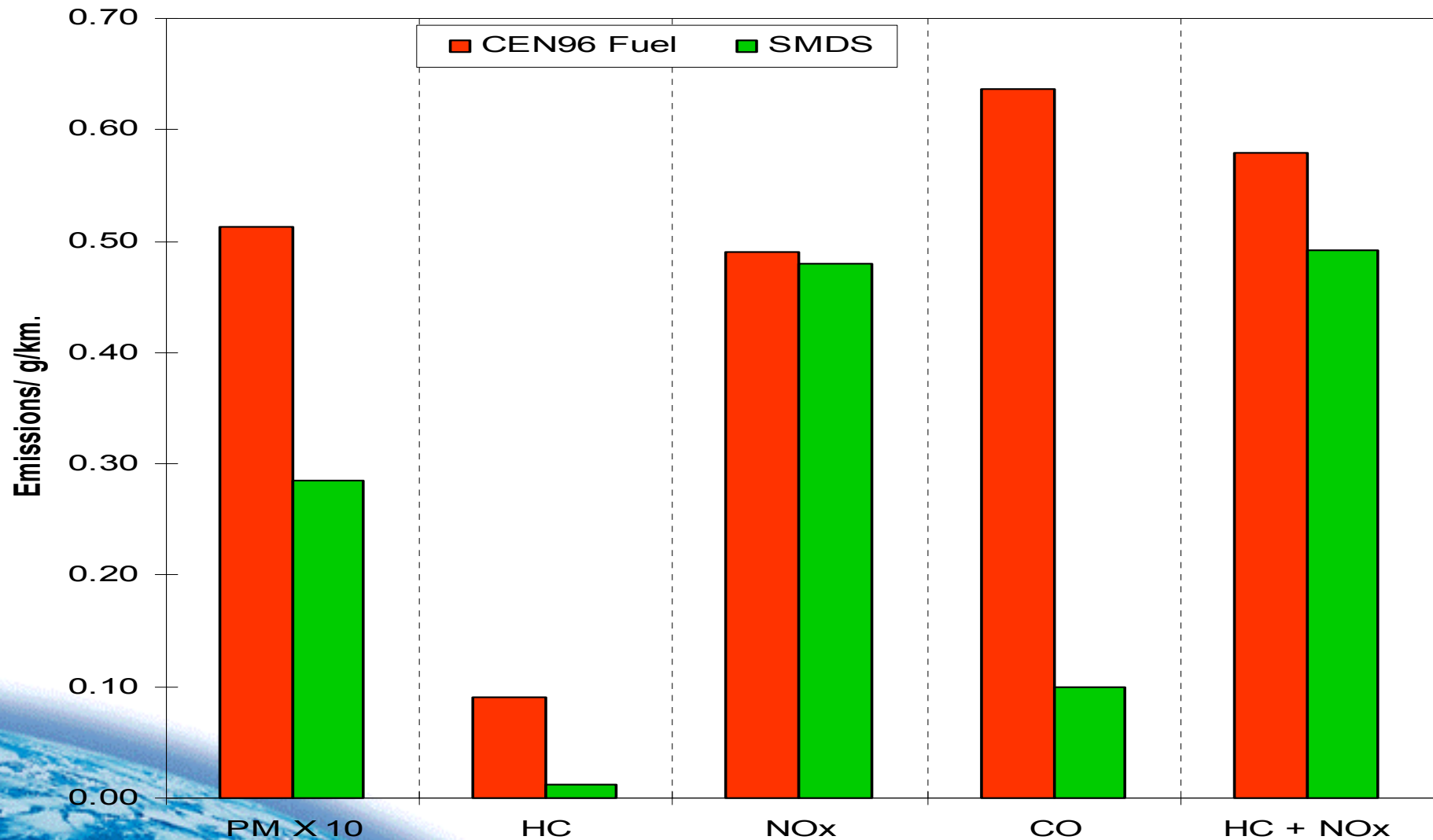
- In-house emissions measurements for 1992, 1996 (Euro-1 & 2) light and heavy duty reported at DEER 2000
- New data for light- & heavy-duty 2000 technology (Euro-3)

## Measurements

- Vehicles, Engines and Test Cycles
  - Year 2000 technology Euro-III or German D-III
  - 5 x Light duty vehicles, 2 x Heavy Duty engines
  - EU test cycles, MVEG for L.Duty & ESC for H.Duty
- Emissions benefits versus standard diesel compared across range of technology levels

# Emissions Performance

## – Light-Duty Fleet with 100% SMDS Diesel



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# Emissions Performance across the technologies

Summarised %benefits for 100% SMDS Diesel

Benefit	Light-Duty			Heavy-Duty		
(%)	Euro I	Euro II	Euro III	Euro I	Euro II	Euro III
PM	42	39	41	18	18	34→10
NO <sub>x</sub>	10	5	5	16	15	5→19
HC	45	63	62	13	23	<9
CO	40	53	75	22	5	16

# Emissions Performance

## -Summary of Results with 100% SMDS Diesel

- Emissions benefits in earlier study evident in newer technologies
  - Moreover, benefits still large & comparable to earlier work

### LD Vehicles

- Large (40%-60%) emissions benefits are achievable by SMDS
  - PM, HC, CO
- NOx emissions benefits are small ~5%

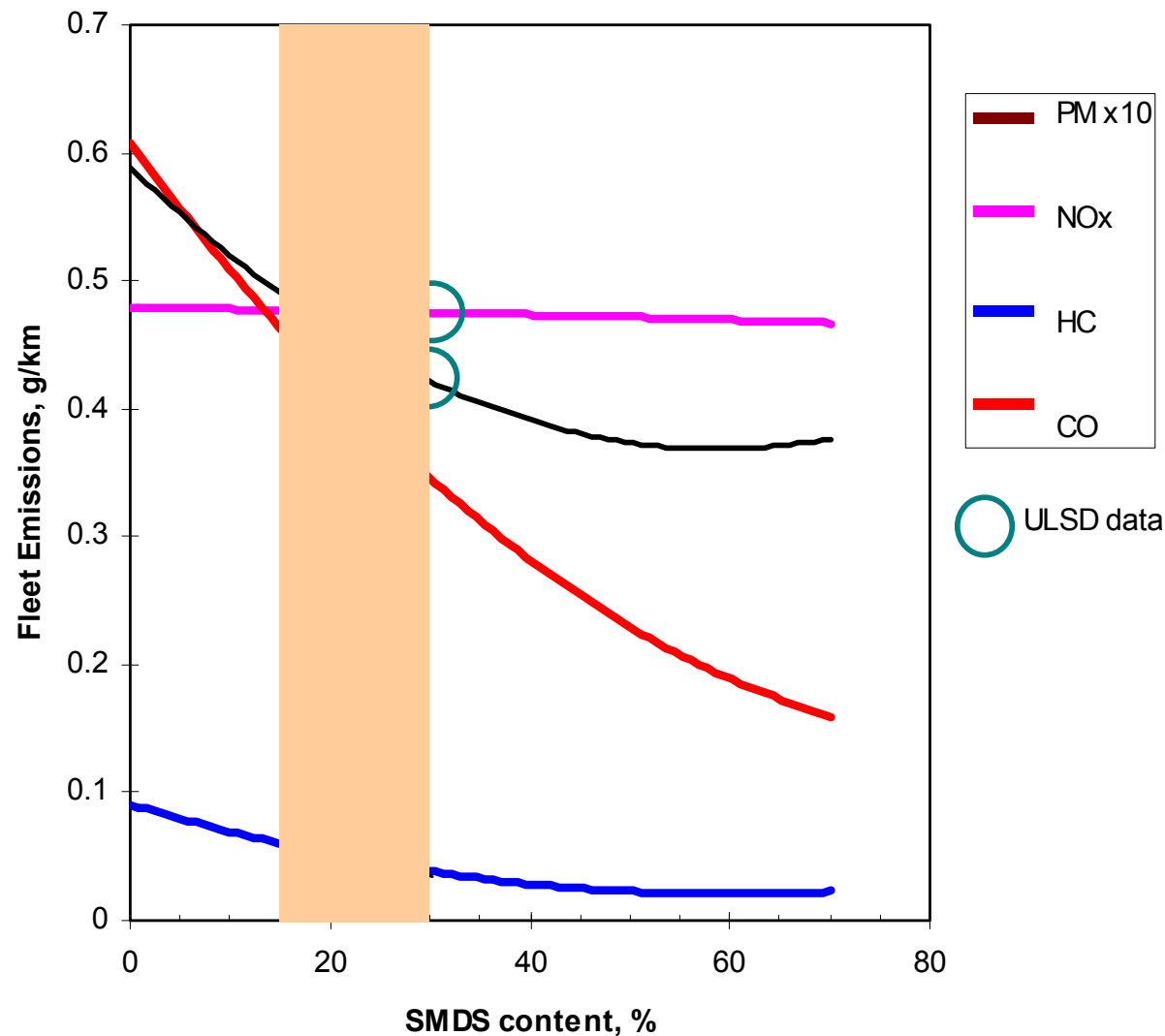
### HD Engine

- Benefits for all emissions smaller than LD, i.e. 5-30% range
  - With Euro-3, issues with both engines of PM-NOx trade-off (tuning issues)
  - PM benefits up, NOx benefits down or vice versa
  - Reasonable supposition that Euro-3 HD benefits similar to earlier technology Euro-1&2



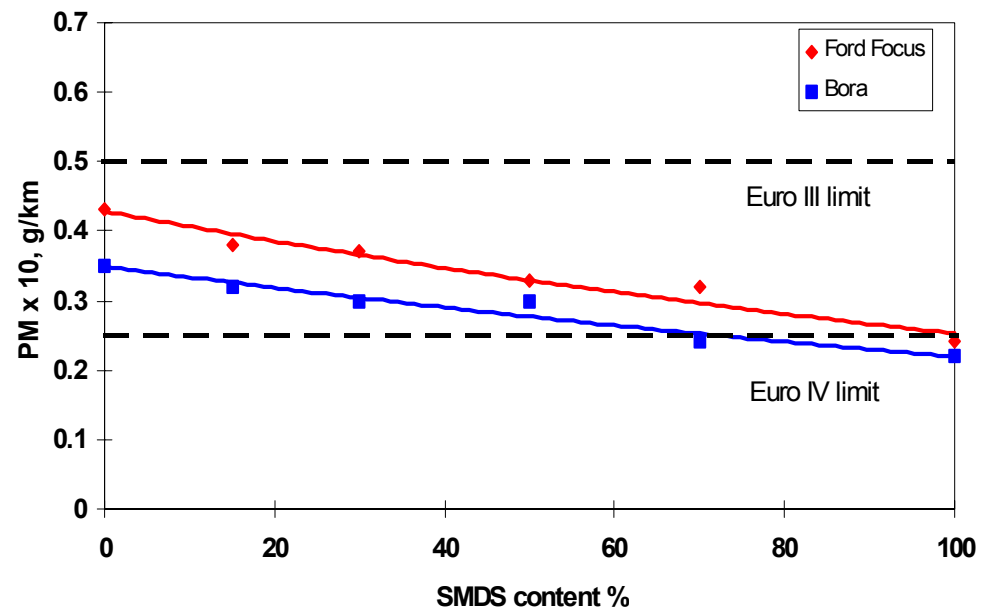
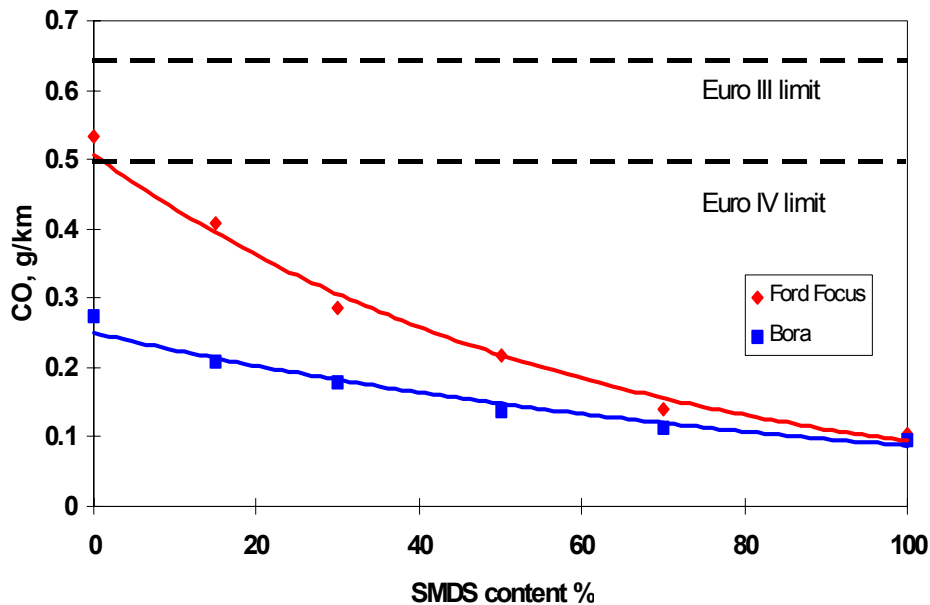
# SMDS Blends –Emissions Benefits

- Strong non-linear effect of SMDS concentration on most emissions
  - large percentage benefits of SMDS achieved for relatively low level of SMDS in fuel blends
  - Blends in 15-30% SMDS range offer a good route to low emissions fuels
  - Performance of blend similar to UK ULSD (50ppm S)
    - Co-fuel  $\rho = 850\text{kg m}^{-3}$  and 400ppm S



# Potential to meet Legislation

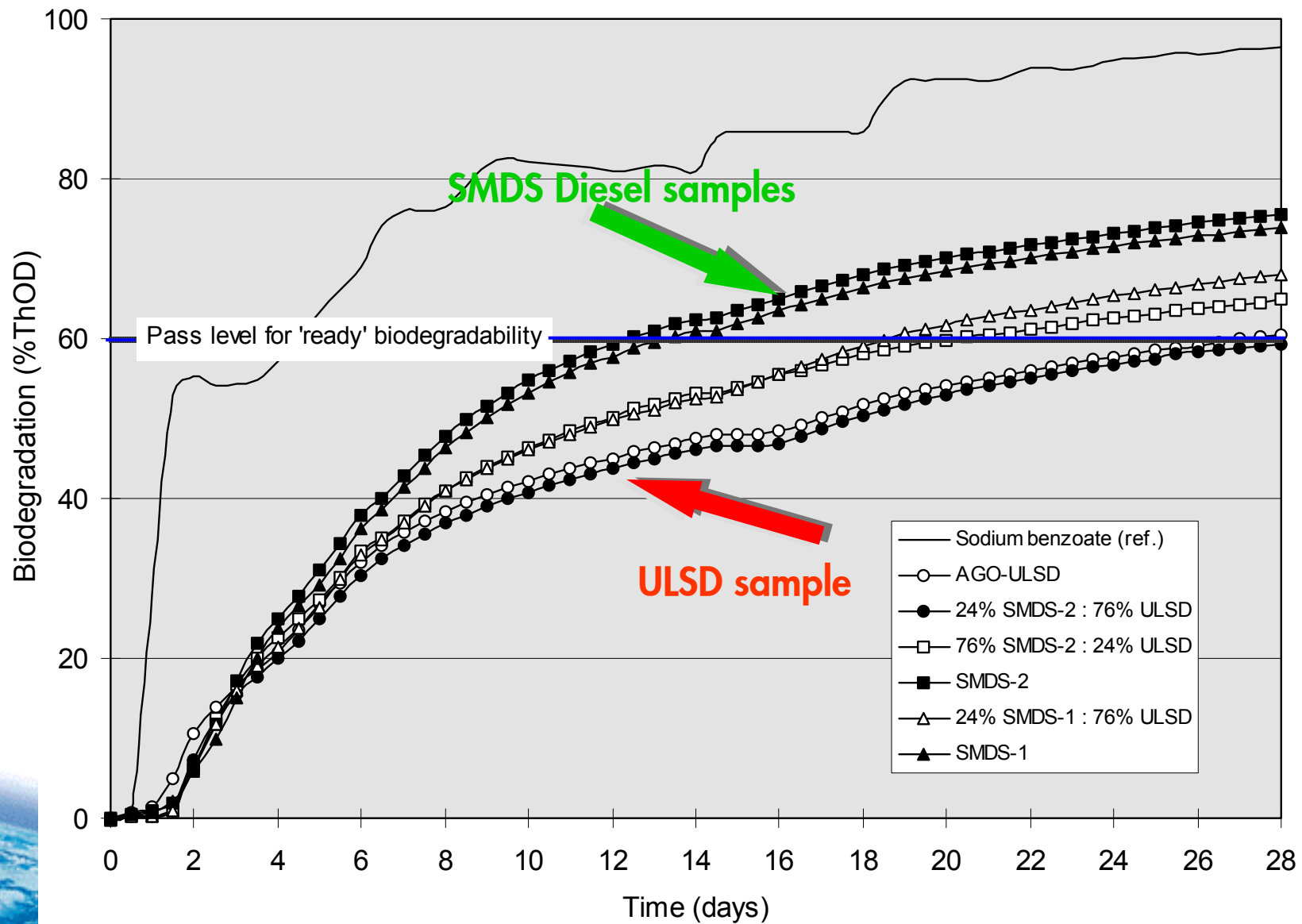
- Can SMDS diesel aid an engine to next stage of legislation ?  
e.g. Euro-III  $\Rightarrow$  Euro-IV (2005) (or D-III  $\Rightarrow$  Euro-III)
  - Euro-III (2000):- PM and CO could be taken inside Euro-IV limit
  - D-III (~1999):- PM and CO taken inside Euro-III limit for ~30% SMDS



# Biodegradability

- Matrix Design (comparison against another clean diesel)
    - AGO - Ultra Low Sulfur Diesel (UK ULSD, nominally  $\leq 50$ ppm S)
    - SMDS-1 Diesel (original Bintulu production)
    - SMDS-2 Diesel (2<sup>nd</sup> generation catalyst production)
    - Mixture of 24% SMDS-1 Diesel : 76% ULSD
    - Mixture of 24% SMDS-2 Diesel : 76% ULSD
    - Mixture of 76% SMDS-2 Diesel : 24% ULSD
- Lowest proportion of 24%,  
Chosen to be below EU limit of 25%  
When assessing substance preparations
- Methodology
    - Biodegradation accessed through oxygen demand
      - OECD Test Guideline 301 F: manometric respirometry
    - Theoretical oxygen demand for complete biochemical oxidation was calculated (ThOD)
    - Extent of biodegradation (BOD) expressed as a percentage of ThOD

# Biodegradability -Results



# Biodegradability

- SMDS-2 diesel ‘readily’ biodegradable according to EU legislation
  - $\geq 60\%$  ThOD in “10 day window”
- SMDS-1 diesel was extensively biodegraded
  - $\geq 60\%$  ThOD at end of test, but just failed “10 day” criterion for ‘ready’ biodegradability
- Biodegradabilities of SMDS-1 & SMDS-2 diesel were significantly higher than clean diesel reference (ULSD, 50ppm S)
- Difference expected to be greater with other diesels (>50ppm S specs), as their aromatic content usually higher than ULSD reference
- ULSD and blends with SMDS diesel were also extensively biodegraded ( $\geq 60\%$  ThOD) in OECD 301 F.

# Ecotoxicity

- Acute toxicity of Water Accommodated Fractions (WAFs) assessed following OECD Test Guidelines 201-203 to:-
  - *Raphidocelis subcapitata* (algae) (201)
  - *Daphnia magna* (water flea) (202)
  - *Pimephales promelas* (fathead minnow) (203)
- Results for aquatic toxicity tests expressed in loading rates (mg/l) for no observed effect (NOEL) or 50% effect (EL<sub>50</sub>)
- Fuels and Blends tested
  - 1) 100% SMDS-2 diesel
  - 2) Blend of 24% SMDS-2 diesel : 76% ULSD
  - 3) Blend of 50% SMDS-2 diesel : 50% ULSD
  - 4) Blend of 76% SMDS-2 diesel : 24% ULSD
  - 5) 100% Conventional diesel (ULSD, nominal 50ppm S)

# Ecotoxicity - Results

- Definitions
  - $1\text{mg/l} < \text{EL50} < 10\text{mg/l}$  “toxic” to aquatic organisms
  - $10\text{mg/l} < \text{EL50} < 100\text{mg/l}$  “harmful” to aquatic organisms
  - $100\text{mg/l} < \text{EL50}$  “not harmful” to aquatic organisms

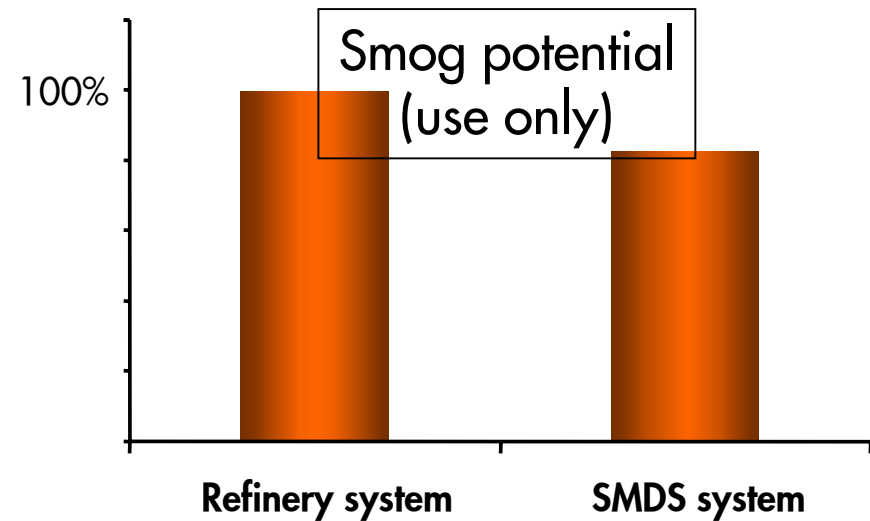
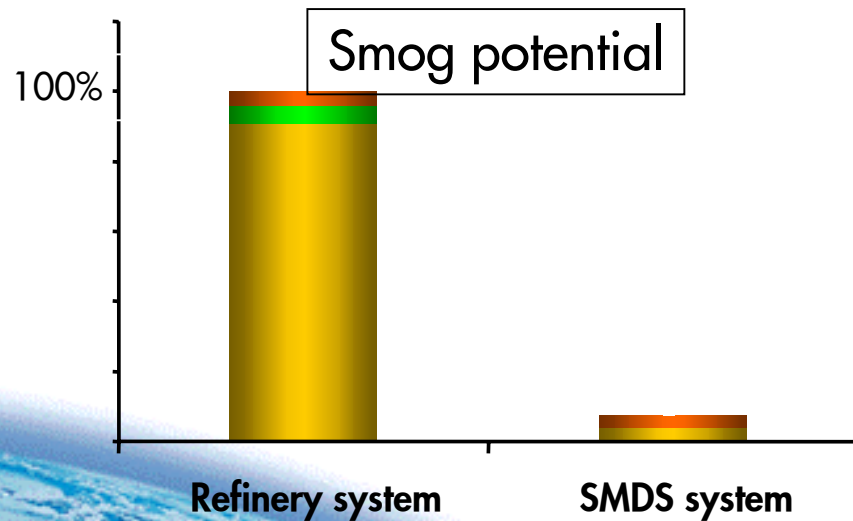
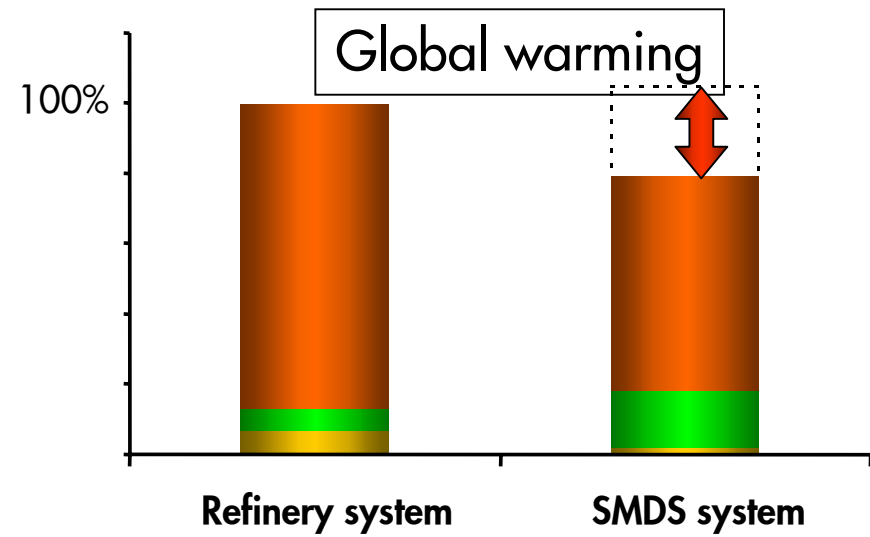
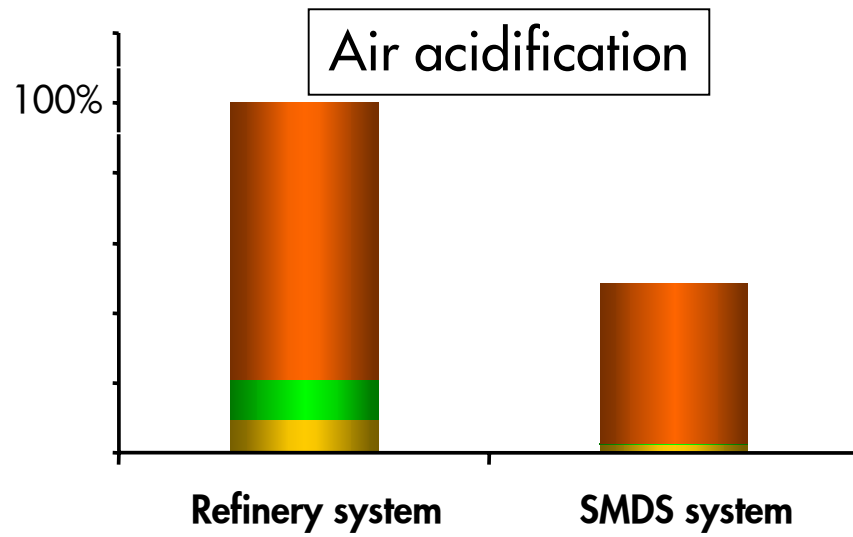
## Results

- SMDS is non-toxic to *D. Magna*, *R. subcapita* & *P. promelas* under current EU criterion
  - Tested at  $1000\text{mg/l}$  cf.  $100\text{mg/l}$  criterion
- Blends tested for 2 species, *D. Magna*, *R. subcapita*,
  - 76% and 50% blends too would be classified as “not harmful” to aquatic organisms

# Sustainability


- Typically assessed against economic, social and environmental considerations
  - should include entire life cycle of process: feedstock production, conversion and product usage
- As production route of transportation fuels & chemical feedstocks, SMDS diesel likely to score well on all three sustainability criteria
  - e.g. should offer clear lifecycle benefits for NO<sub>x</sub> and SO<sub>2</sub> emissions
- Specific issue of Greenhouse gases comparison more complex.
  - Carbon efficiency of SMDS process currently lower than typical leading refinery
  - Benefits upstream & product usage will (more than) offset this
  - Vehicle fuel usage gives CO<sub>2</sub> benefits of up to 5%
    - Higher caloric value and higher H/C ratio
- Full “SMDS and the environment” study, covering greenhouse gas emissions is available
  - Study by PwC

# PwC Life Cycle Study Results



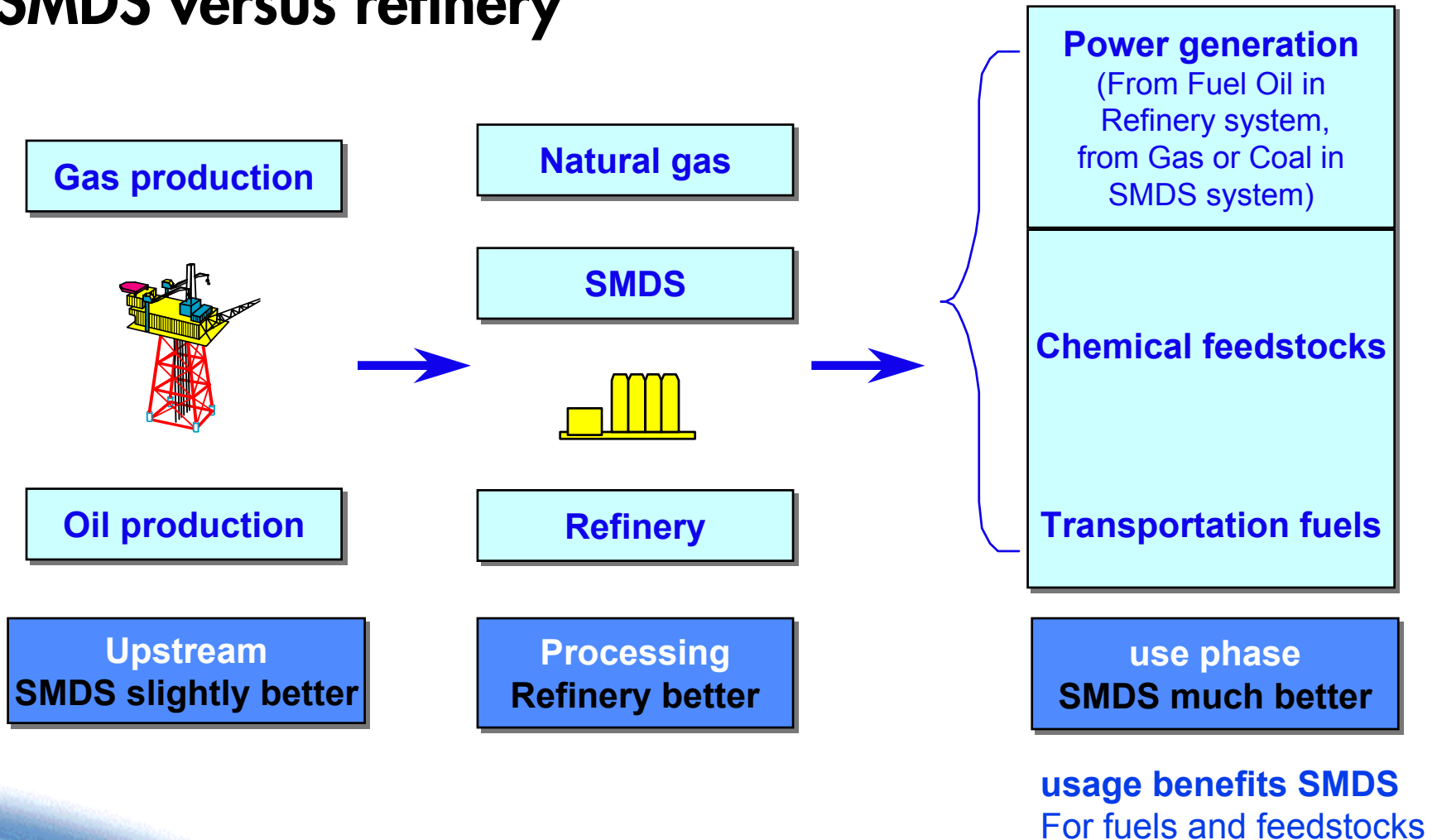
 Extraction of feedstock

 Production of products

 Use of products

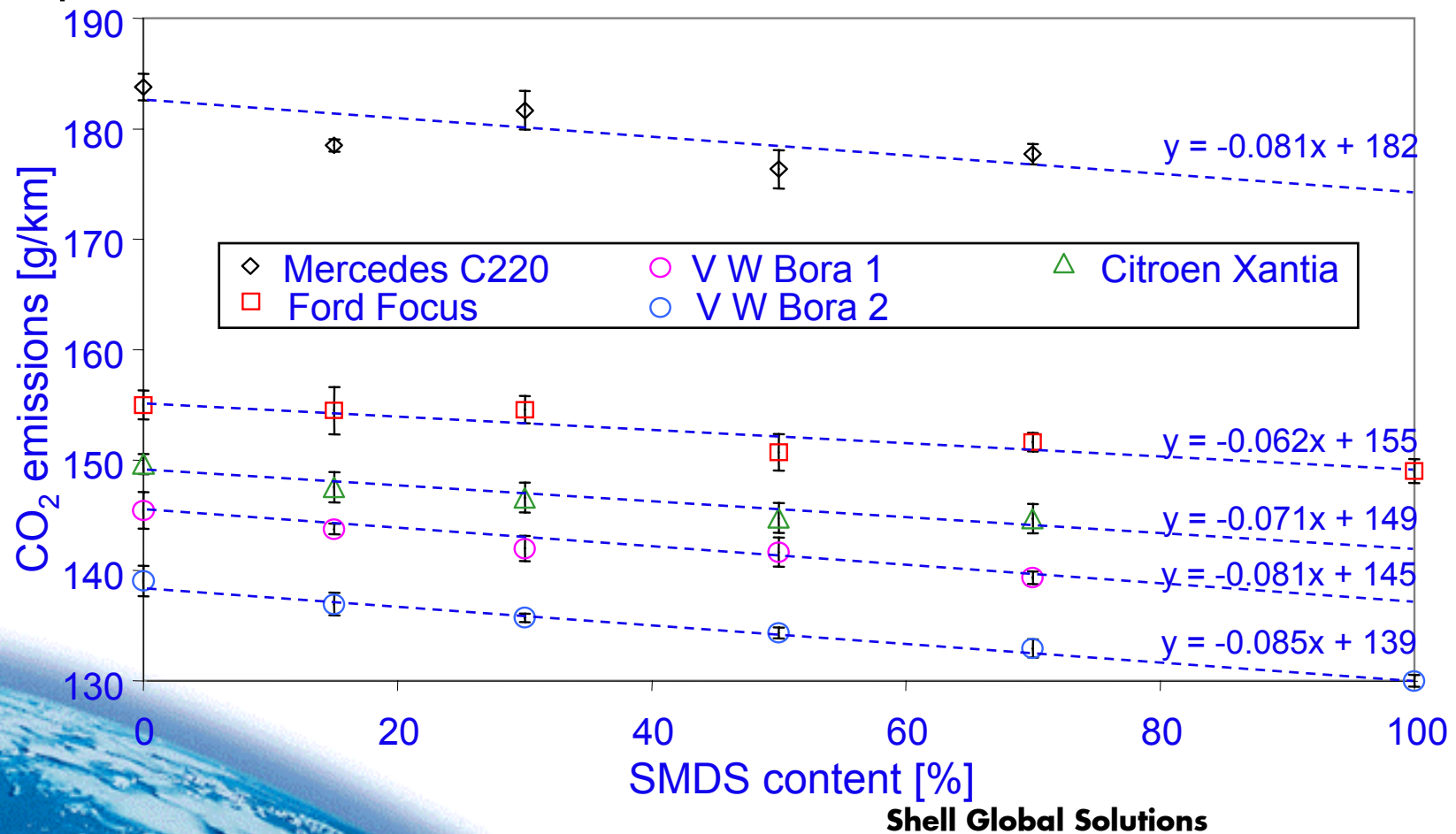
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# Life cycle comparison on CO<sub>2</sub> emissions: SMDS versus refinery



# CO<sub>2</sub> emissions

- CO<sub>2</sub> tank-to-wheels benefits of ~5% for 100% SMDS
  - Via better calorific value (2.5%) and higher H/C ratio
  - In non-optimised engines
- Proportion of those benefits in blends



# Conclusions

- Whilst traditionally GTL fuels have been viewpoint of improved emissions performance, its unusual properties offers other benefits, which have been confirmed through experiments
  - Biodegradability
  - Ecotoxicity
- Sustainability has been examined in terms of
  - 1) An assessment of the entire production, processing and usage phases (all products) (PWC study)
  - 2) “Tank-Wheels” CO<sub>2</sub> emissions for diesel vehicles
- Emissions benefits are confirmed across a range of engine and vehicle technologies
  - 1992 - 2000

## Recent Activities – Field Trials

- Working with partners in US, Japan and EU to test the fuel under field trial conditions, e.g. NREL
  - Validate performance over many months of real “on the road” conditions
- Commercially purchased fuel has been used by a California fleet



## Recent Activities – Market Launches

Shell Pura Diesel has been developed as a premium fuel for Thailand. The unique base fuel is a blend of standard diesel fuel and Shell's propriety SMDS gasoil.

Shell Pura Diesel will initially be available at 150 Shell service stations in Bangkok from Monday 21st January 2002. Distribution will soon be available throughout the country.

As Shell Pura Diesel is a more technologically advanced product, with a blend of synthetic gasoil and a top-tier additive package, the cost of the product is slightly higher.

*Extract from press release*



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